Overview of the Accumulator Transverse Core Stochastic Cooling Upgrade

Dave McGinnis

May 17, 2002

Overview

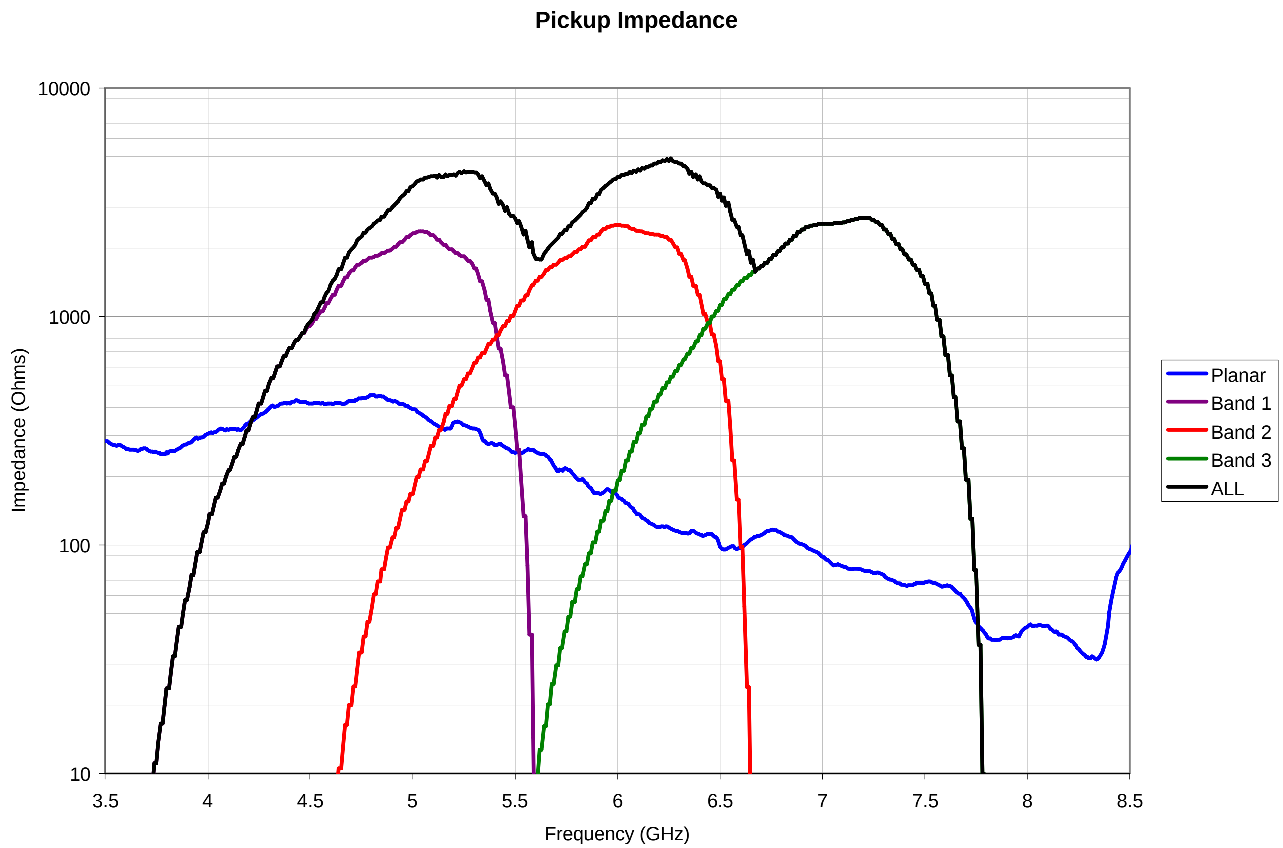
- The horizontal emittance of a typical 100E+10 antiproton stack is about a factor of 2 larger than the Run II handbook design value.
- We have developed a two-fold plan to reduce the transverse emittance:
  - Better transverse stochastic cooling of the Accumulator core.
    - The bandwidth will increase by a factor of 2
    - The center frequency of the band will increase by a factor of 1.5
  - Dual lattice operation mode of the Accumulator
    - Keep the “fast stacking” lattice (η=0.012) for pbar production
    - During shot setup, ramp the lattice with the beam at the core orbit to the “IBS” lattice (η=0.022)
      - The “IBS” lattice will reduce the intra-beam scattering heating by a factor of 2.5
      - The “IBS” lattice will increase the cooling rate by a factor of two increase in mixing due to the change in η

$$\frac{d\varepsilon}{dt} \approx -\frac{\varepsilon}{\tau_{cool}} + \frac{Heat}{\varepsilon^{3/2}}$$

$$\frac{\varepsilon_{old}}{\varepsilon_{new}} = \left(\frac{\tau_{cool_{old}}}{\tau_{cool_{new}}}\frac{Heat_{old}}{Heat_{new}}\right)^{2/5} = \left(\underset{\text{Bandwidth}}{2}\times\overset{\text{Center freq.}}{1.5}\times\underset{\text{Better Mixing}}{2}\right)^{2/5} \times \left(\frac{\overset{\text{Ions}}{0.4}+\overset{\text{IBS}}{0.6}}{0.4+\frac{0.6}{\underset{\text{Reduced IBS}}{2.5}}}\right)^{2/5} = 2.4$$

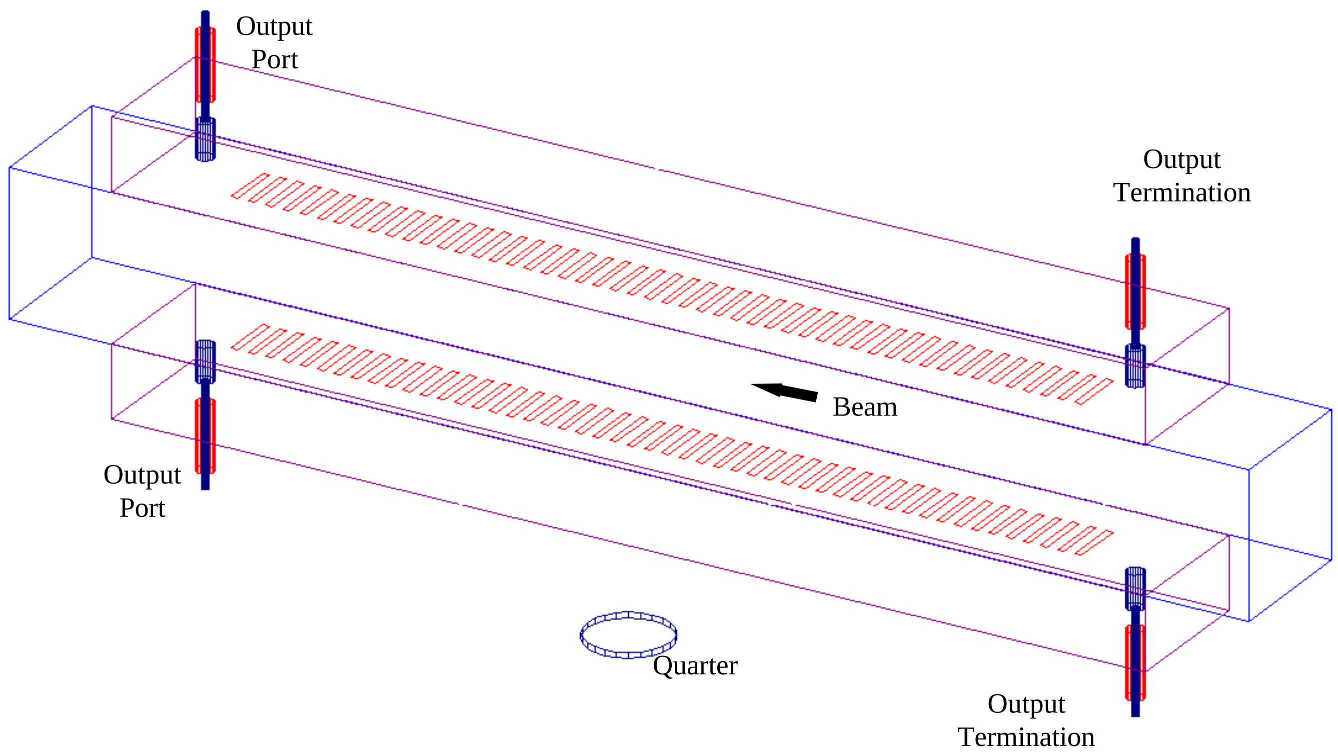
Accumulator Core Cooling Upgrade

- Present system consists of a 2-4 GHz band and a 4-6 GHz band
  - The 2-4 GHz band is ineffective because of the small value of η
  - The 4-6 GHz band suffers from poor signal to noise.
- Replace both core bands with a 3 band Debuncher style system
  - Better sensitivity
  - More bandwidth (2x)
  - Better mixing factor (1.5x)
  - Installed in June 2002



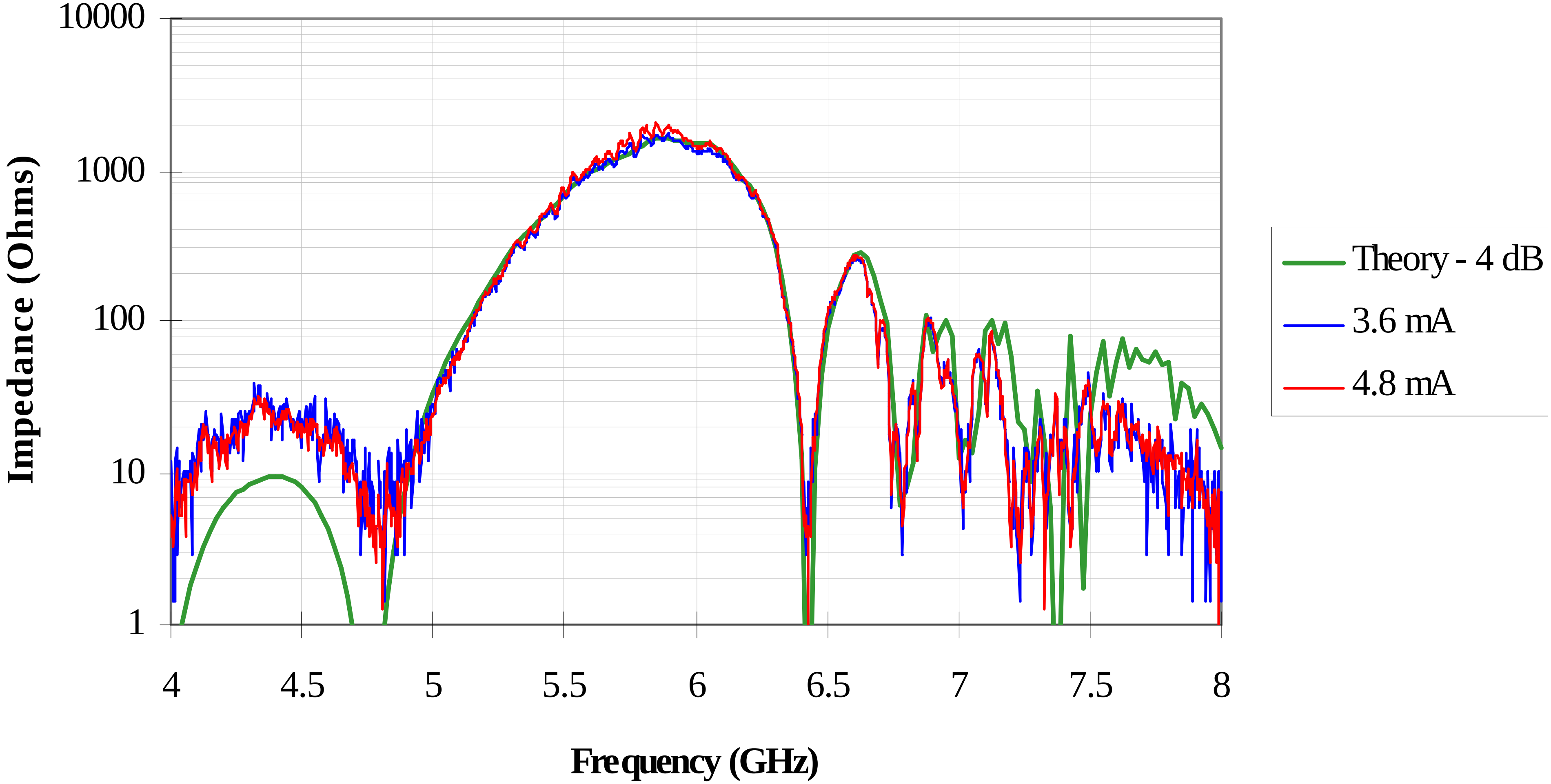
Slow Wave Structures

- The core cooling upgrade consists of slow-wave structures
- When the beam pipe can support a microwave mode (> 5 GHz in the Accumulator), binary combiner boards become ineffective
- The beam pipe of a slow-wave structure is designed to be above cutoff
- The slots of a slow-wave structure slow the phase velocity of the waveguide to match the beam velocity



Slow Wave Structures

- Slow wave structures are simple enough that their response can be accurately simulated with moment-method code.

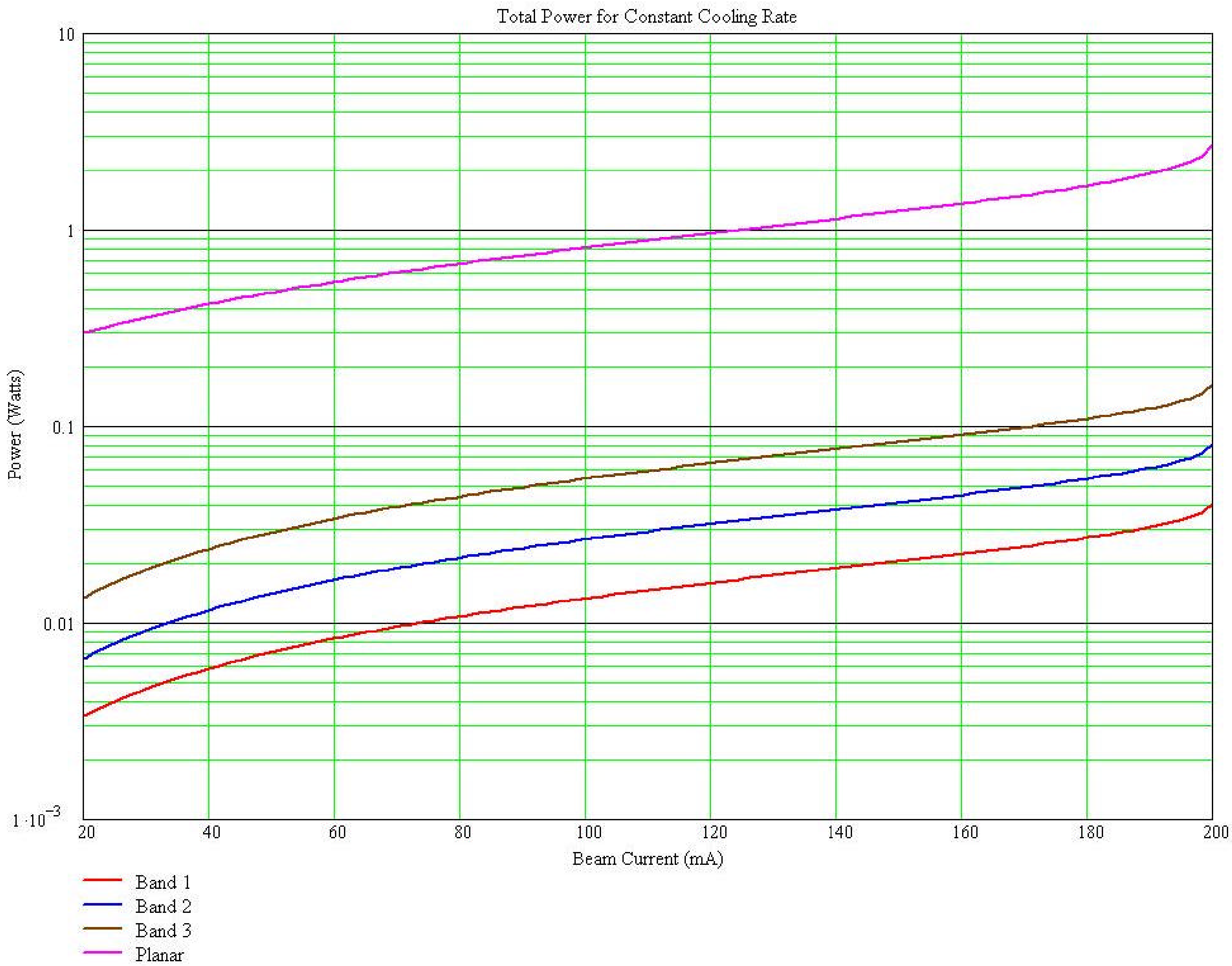


Some Parameters

Band	Wave guide	Center Freq (GHz)	Freq Span (GHz)	Waveguide Width (inches)	Waveguide Height (inches)	Beam Pipe Width (inches)	Beam Pipe Height (inches)
1	WR-187	5	1.3	1.872	0.872	1.872	1.244
2	WR-159	6	1.3	1.59	0.795	1.59	1.244
3	WR-137	7	1.3	1.372	0.622	1.372	1.244

Band	Array Length (inches)	No. of Slots	Launcher Room (inches)	Slot Width (inches)	Slot Spacer (inches)	Slot Length (inches)	Peak Impedance (Ohms)	Effective Bandwidth (GHz)
1	10.6	48	1.5	0.08	0.08	0.814	2352	1.082
2	10.6	48	1.5	0.08	0.08	0.679	2510	1.166
3	10.6	48	1.5	0.08	0.08	0.575	2704	1.263

Power Calculations

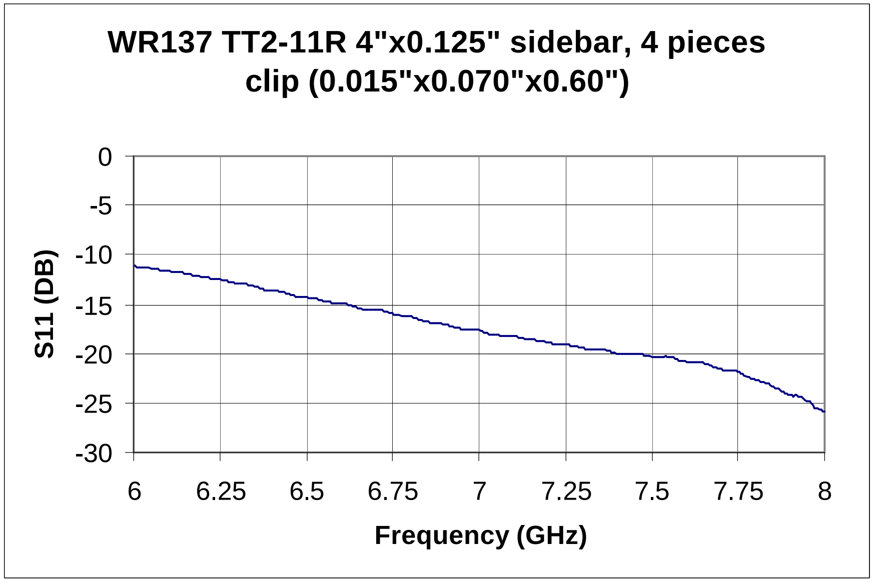


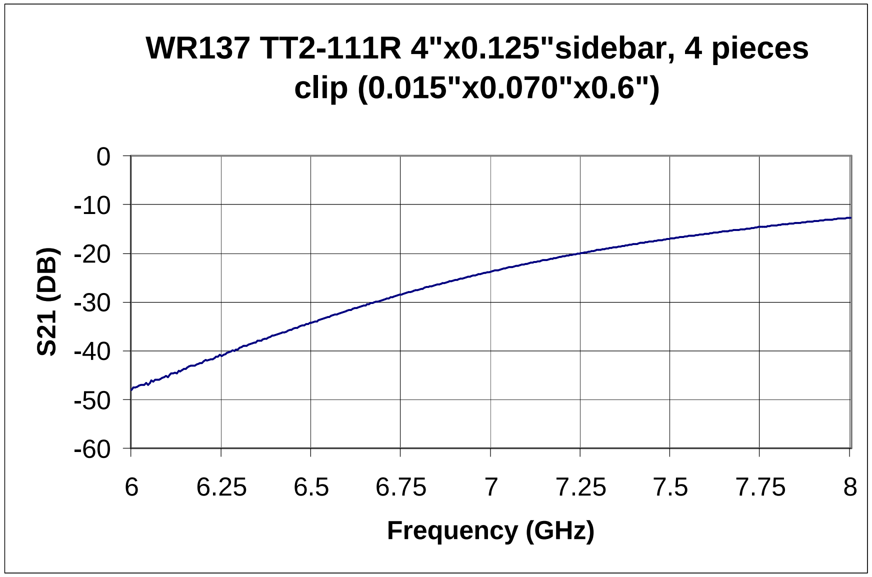
Power Estimates

- Power Estimates
  - Present Planar loop design
    - @120 mA - 5.3 W
    - @200 mA - 2.7 W
  - 3 Band Design
    - @120 mA – 0.17 W / band
    - @ 200 mA – 0.1 W / band
    - 50% goes in downstream beampipe absorber
    - 50% goes in downstream input waveguide terminations
  - Spec. is 2 Watts / band

Absorber Design

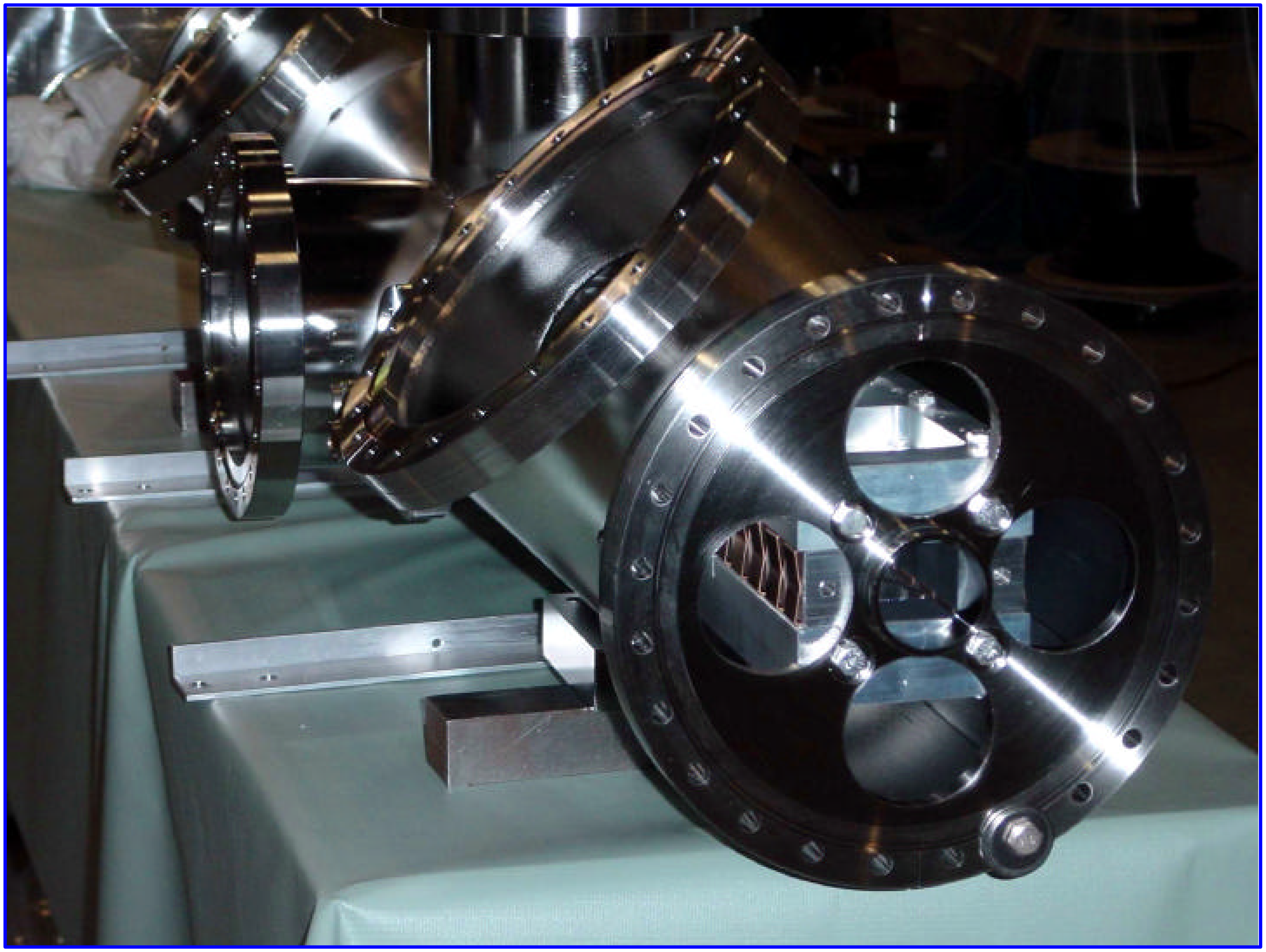
- Band1 to entrance
  - reflection: -21 --- -23 db
  - attenuation: -70 --- -30 db
- band1 to band2
  - reflection (band1 side) -20 --- -25 db
  - reflection (band2 side) -21 --- -26 db
  - attenuation (band1 to band2) -60 --- -40 db
  - attenuation (band2 to band1) -45 --- -20 db
- band2 to band3
  - reflection (band2 side) -23 --- -25 db
  - reflection (band3 side) -27 --- -29 db
  - attenuation (band2 to band3) -70 --- -30 db
  - attenuation (band3 to band2) -42 --- -20 db
- band 3 to exit
  - reflection: -28 --- -32 db
  - attenuation: -37 --- -17 db



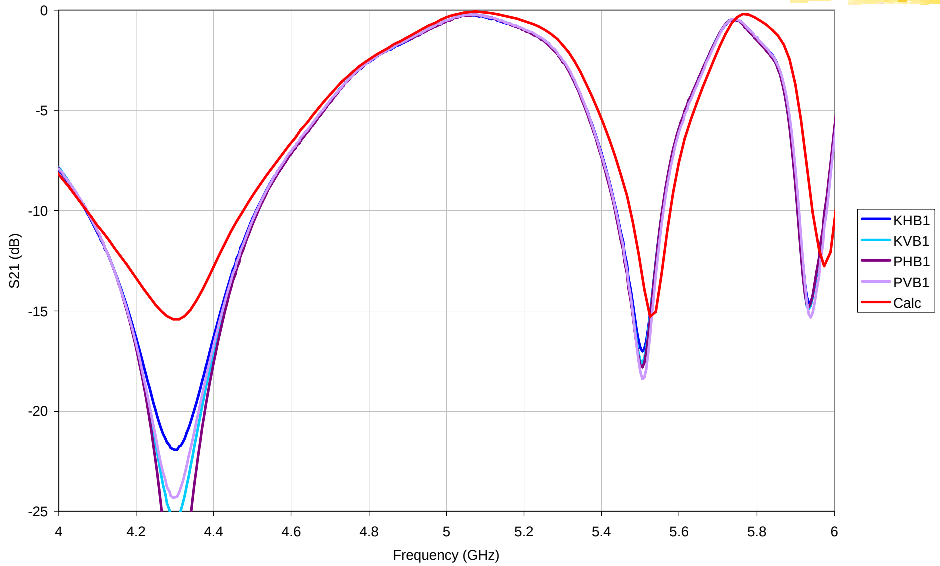


Core Cooling Arrays

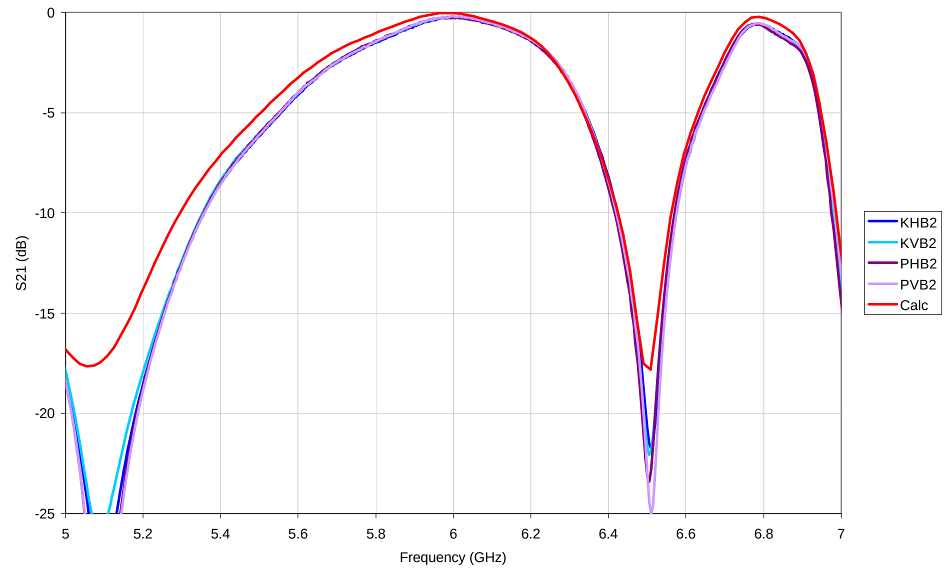
Core Cooling Tank



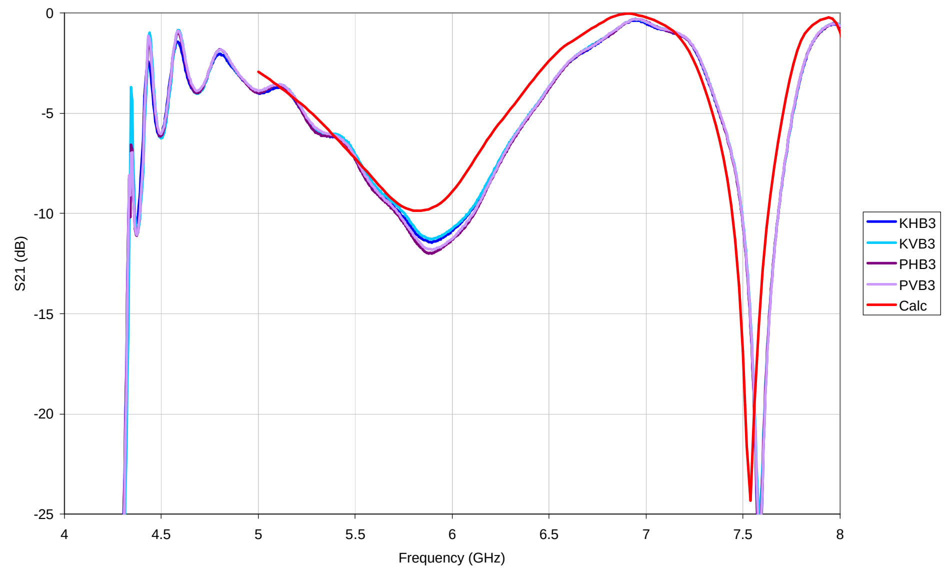
Measured Array S-parameters



Band 1



Band 2



Band 3

Ready to Go!

- All tanks assembled and leak tight.
- All electronics are here and tested.
- All electronic sub-assemblies complete.
- Will perform a microwave power test on a kicker tank
  - Need to bake tank to get to 10^{-10} vacuum
- Start installation Monday June 3, 2002 (could start today)
- Finish installation Friday June 14, 2002
- Start beam commissioning Saturday June 15, 2002
- Finish beam commissioning Sunday June 16, 2002

Some Areas of Concern

- The loss of the 2-4 GHz system to reach into the stacktail during stacking
- Common mode rejection
- Large number of electronic parts (6 systems instead of 4)
- Ferrite TT2-111R under power in the Accumulator
  - We have measured the vacuum properties of the ferrite at elevated temperatures.
  - We have a lot of experience with this ferrite TT2-111R in:
    - The accumulator stacktail
    - Accumulator experiment APEX
    - Debuncher kicker tanks @ 640 Watts / meter (compared to 4 Watts / meter in upgrade)
  - We will do a final power microwave power test.
- Double Bake

Summary

- Slow-wave structures are a proven technology in the Debuncher.
- We've kept the same team in place that built the Debuncher cooling systems
  - Microwave engineers and techs.
  - Mechanical engineers and techs.
- Slow-wave structures are much simpler then present planar arrays
  - Easier to build
  - Better vacuum properties
  - Better electrical properties
- Tank design is universal which simplifies installation.
- Tank stands and controls are unchanged.

Agenda

- Project Overview - Dave McGinnis
- Mechanical Design Overview - Dave Tinsley
- Electrical Design Overview - Pete Seifrid
- Electrical Installation Schedule - Pete Seifrid
- Mechanical Installation Schedule - Henry Gusler
- Baking System - Don Poll
- Electrical Commissioning - Ralph Pasquinelli

Accumulator Core 4-8 GHz Transverse Stochastic Cooling Upgrade

- Run 2A project.
- Project is critical in increasing luminosity in the Collider.
- This project specifically targets large transverse pbar emittances at extraction.
- 1 pickup tank per plane.
- 1 kicker tank per plane.
- 2 planes for a total of 4 tanks.

Tank

The tanks are made from 304L stainless steel that has been hydrogen degassed and electropolished.

- 52 inch long tank, same as previous tank.
- 8 inch tube size, smaller than previous tank.
- All 4 tanks assemblies use the same parts to build them.
- The way the arrays are orientated in the tank and the orientation of the tanks in the beam make up the 4 different types of tanks.
- Re-use of existing tank stands, ion pumps, ion gauges, and titanium sublimation pumps reduce the cost and time spent.

Vacuum Bake Tests

Several tests were done to ensure the new Stochastic Cooling Tanks would pump down into the 1E-10 Torr vacuum range.

- Test the ultimate vacuum on a baked empty vacuum chamber. Record vacuum readings, time and date.

- Place ferrites in the test vacuum chamber. Re-bake the vacuum chamber. Before or after cool down no detectable difference was found in vacuum.

- Place semi-rigid coaxial cable in test vacuum chamber. Re-bake the vacuum chamber. Before or after cool down no detectable difference was found in vacuum.

Absorbers Clips

A new absorber clip design was developed to replace the older method of soldering the absorbers to the heat sinks.

- Absorber clip is made from beryllium copper.
- Eliminates the need for soldering.
- Reduces cost by eliminating manufacturing process.
- Faster and easier to assembly.
- Absorber gets attached directly to the side bar.

Heat Removal from Kicker Tanks

The heat sinks are made from 316 stainless steel with welded tube connections.

- 15 watts of heat to remove per tank.
- Heat sinks attach to the outside of the array assembly.
- CPI (compression) water fittings go through the side of the tank with conflat flanges. Vacuum to air connection.
- The CPI water fitting is on the outside of the tank. Water to air connection.

This eliminated brazing and internal water connections that were a source of vacuum leaks of older designs.

Array Assembly

The array uses slotted aluminum foils similar to the Debuncher. Ease of assembly was an important consideration.

- Foils held in place with V shaped beryllium copper clips.

- Round array support rings mounted on the ends of the array assembly makes for quick and accurate assembly into tank. No survey needed for array location inside tank.

- Array assembly is easily inserted into the tank on built in roller bearings.

- Array support rings use of canted coil springs for electrical contacts into the tank end flanges where it makes the square to round transition.

Waveguide

- 3 pairs of waveguides make up the 3 different bands.

- 10.6 inches long for each waveguide pocket.

- Width and depth of waveguide pocket varies with bands 1, 2, and 3.

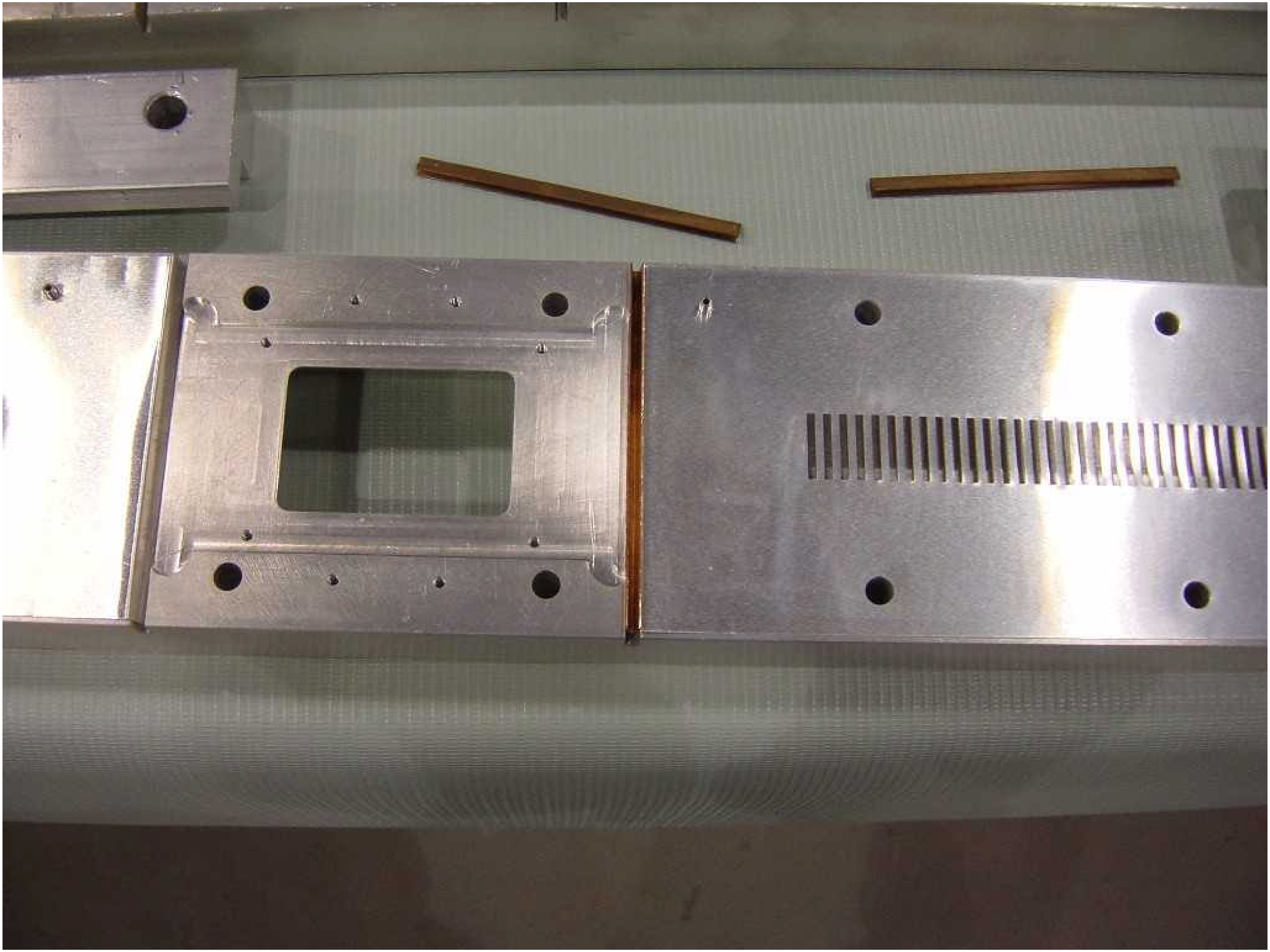
- 5 inches of absorber material at the ends of all the waveguide.

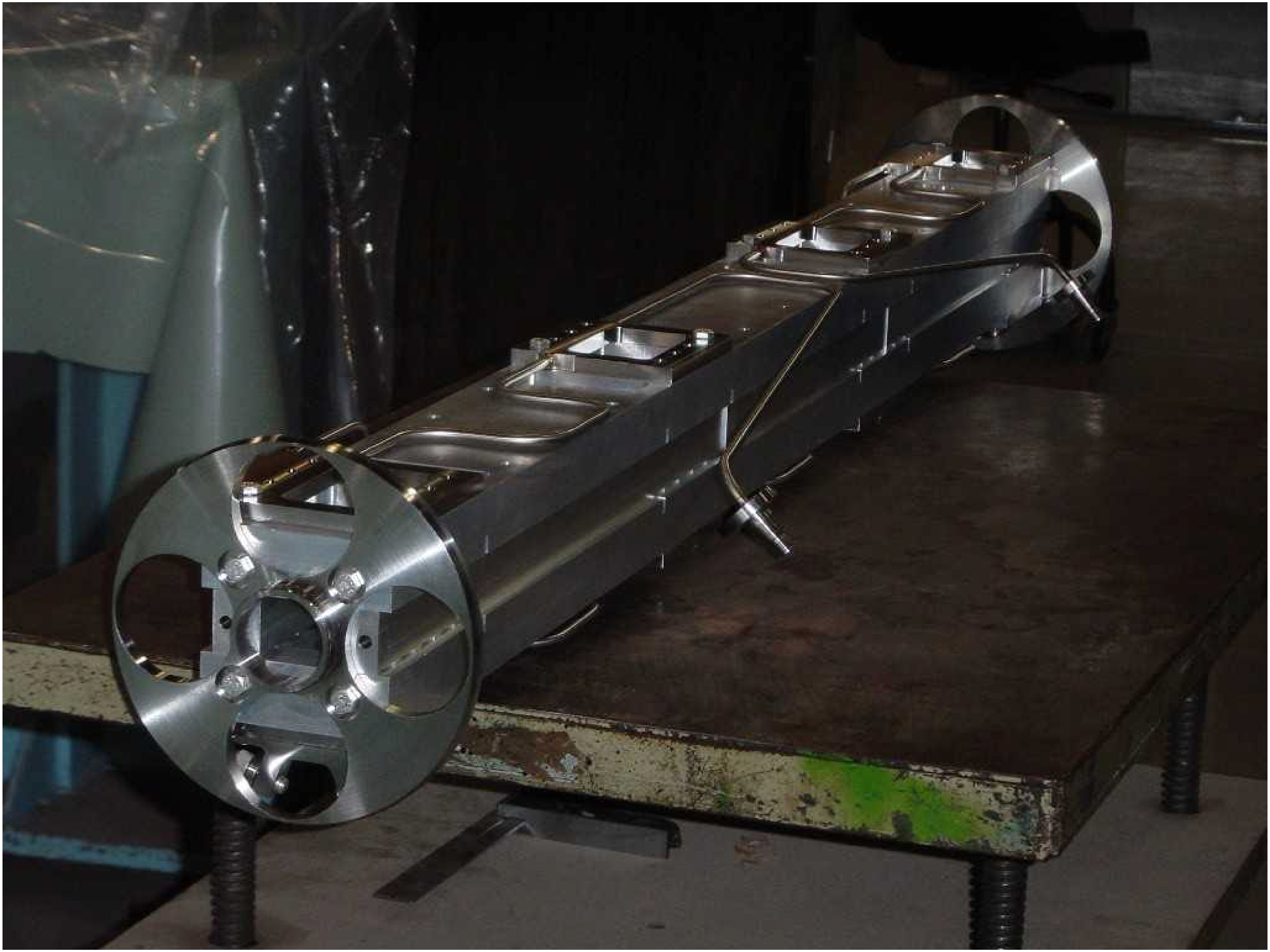
- The soldered launcher assemblies can be removed from the waveguide without disassembling the array assembly.

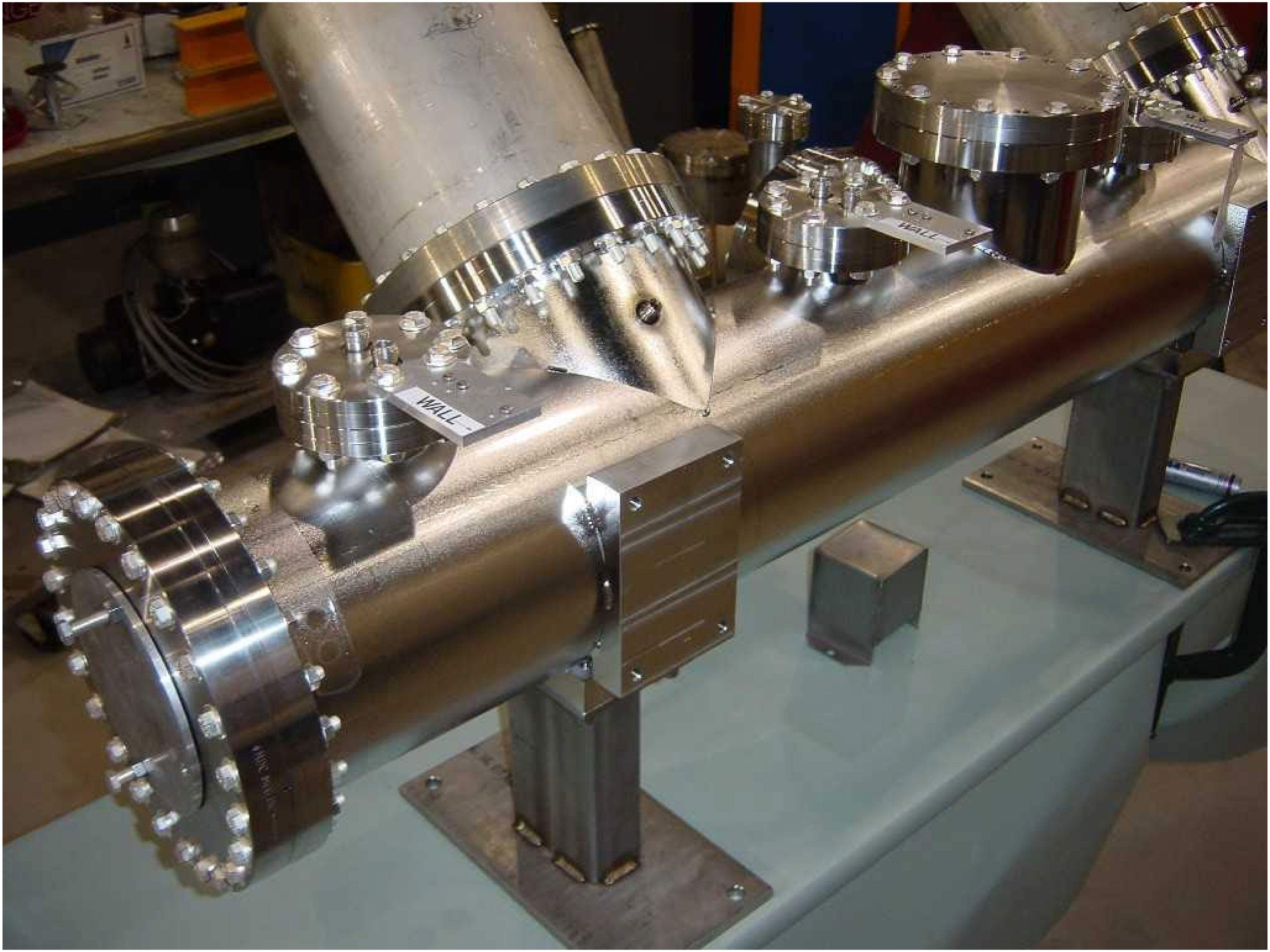
- Ultra high vacuum design. No trapped gasses. Use vented washers under bolt heads. Use vented fasteners on blind holes. Slots in parts were also used for vacuum venting.

Vacuum System (on each tank)

- One ion gauge with screen.
- One 270 l/s ion pump with screen.
- Two 8 inch diameter titanium sublimation pumps with screen
- Each array has eight pumping ports with screens.
- Pumping port screens fit flush with the absorber surface.
- New thermocouple feed-throughs will help eliminate vacuum leaks on previous tanks.
- A total of four thermocouples are attached on each array assembly to monitor the 125 C° vacuum bake.



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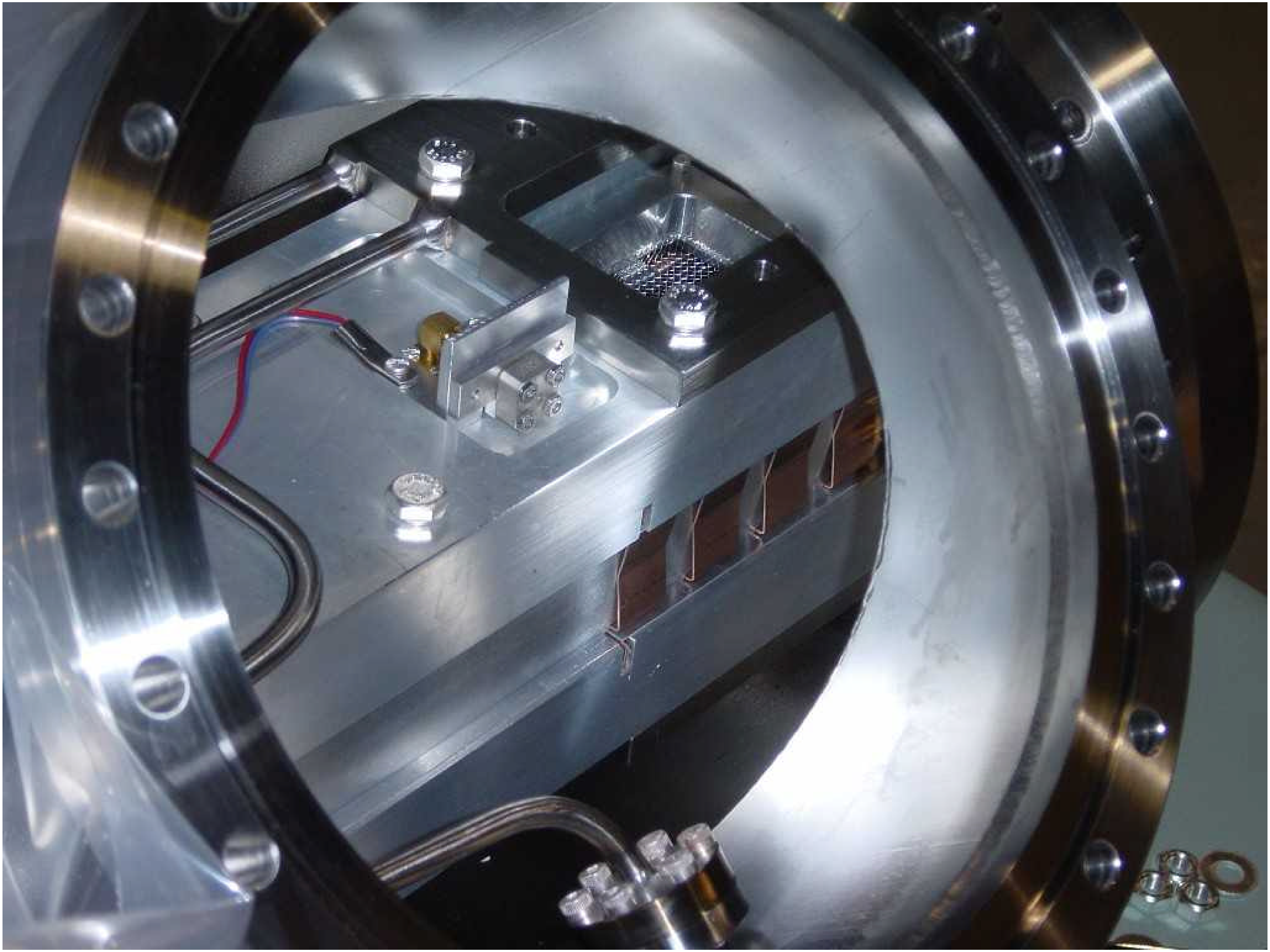
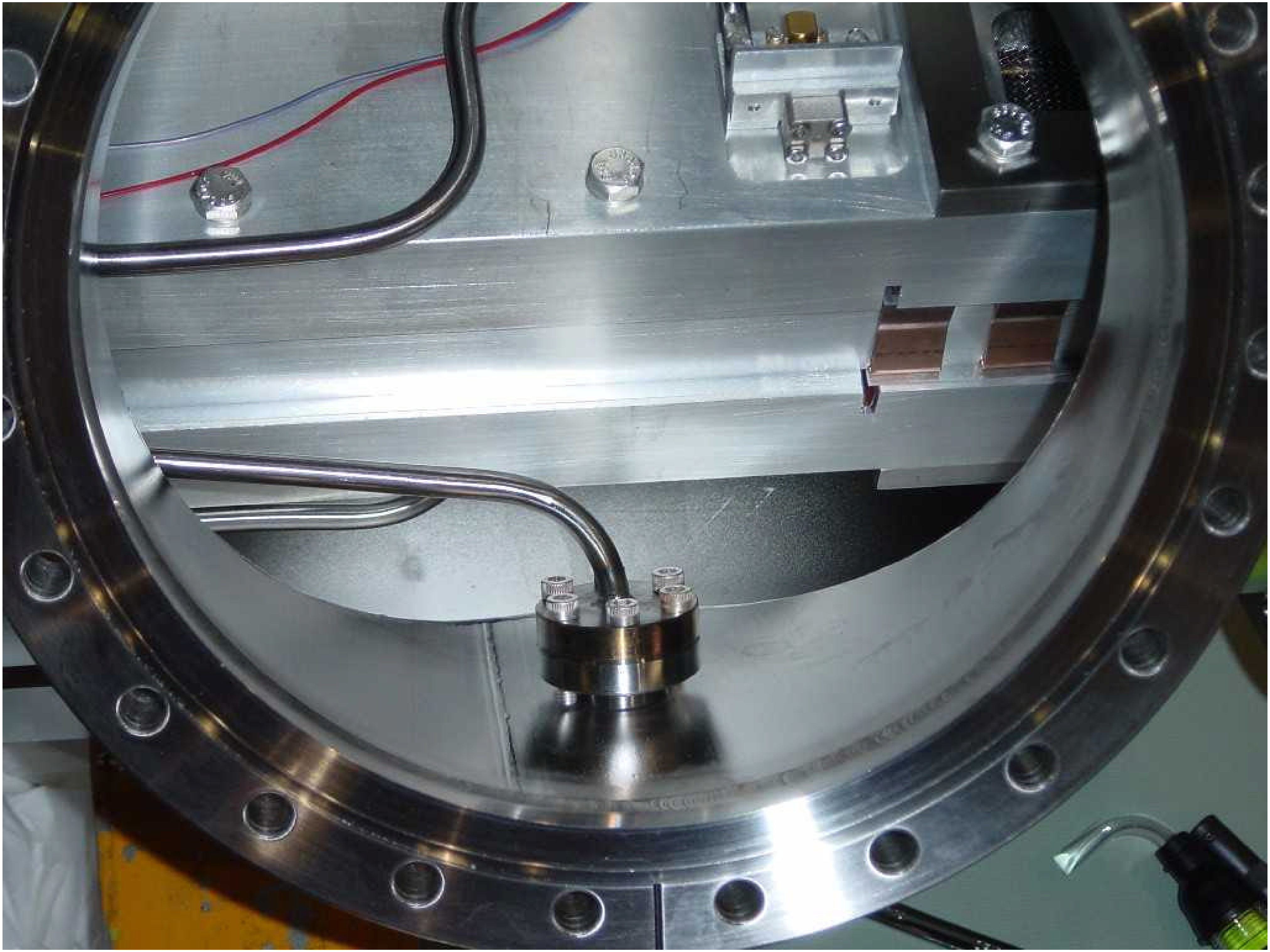
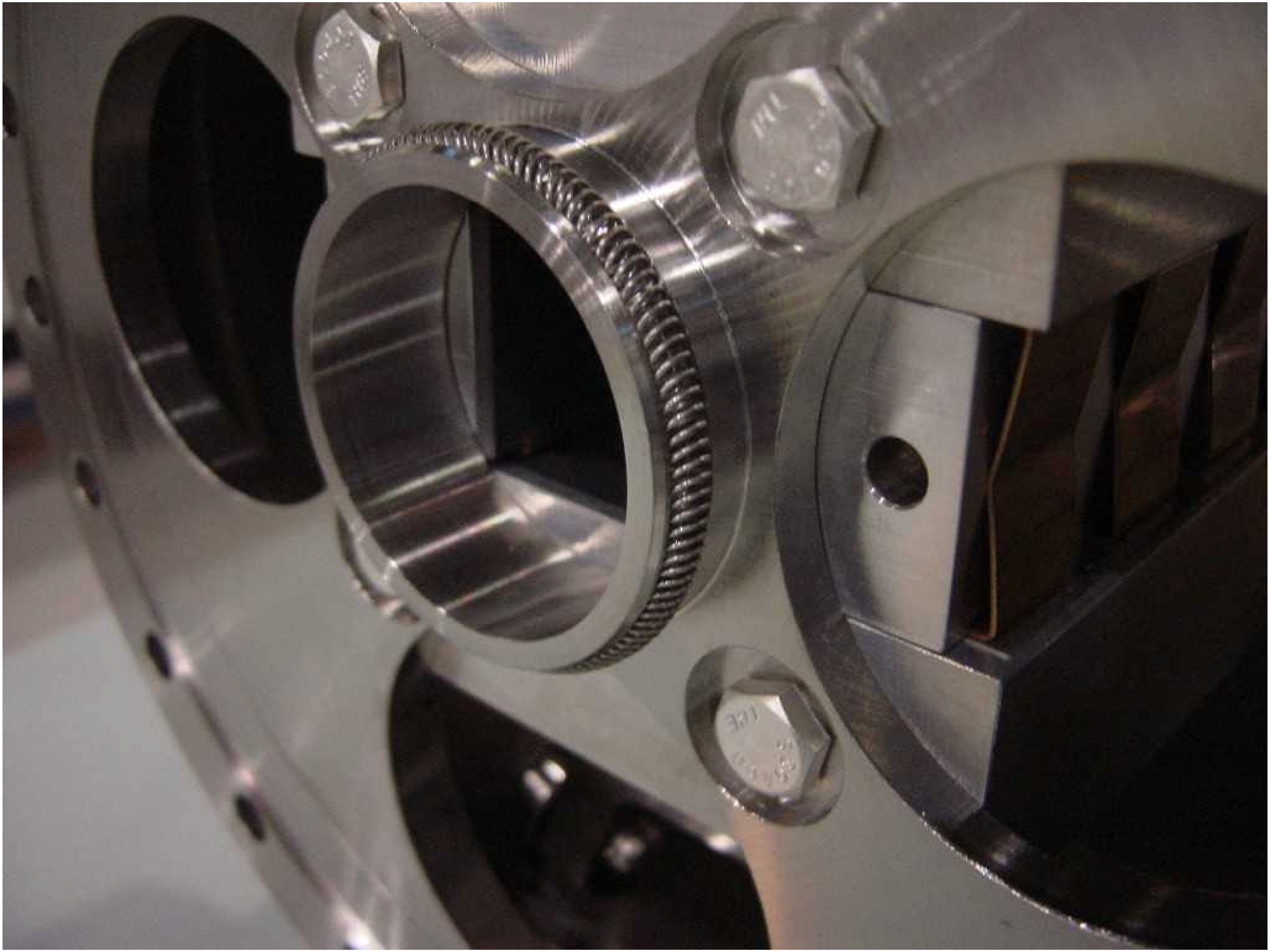
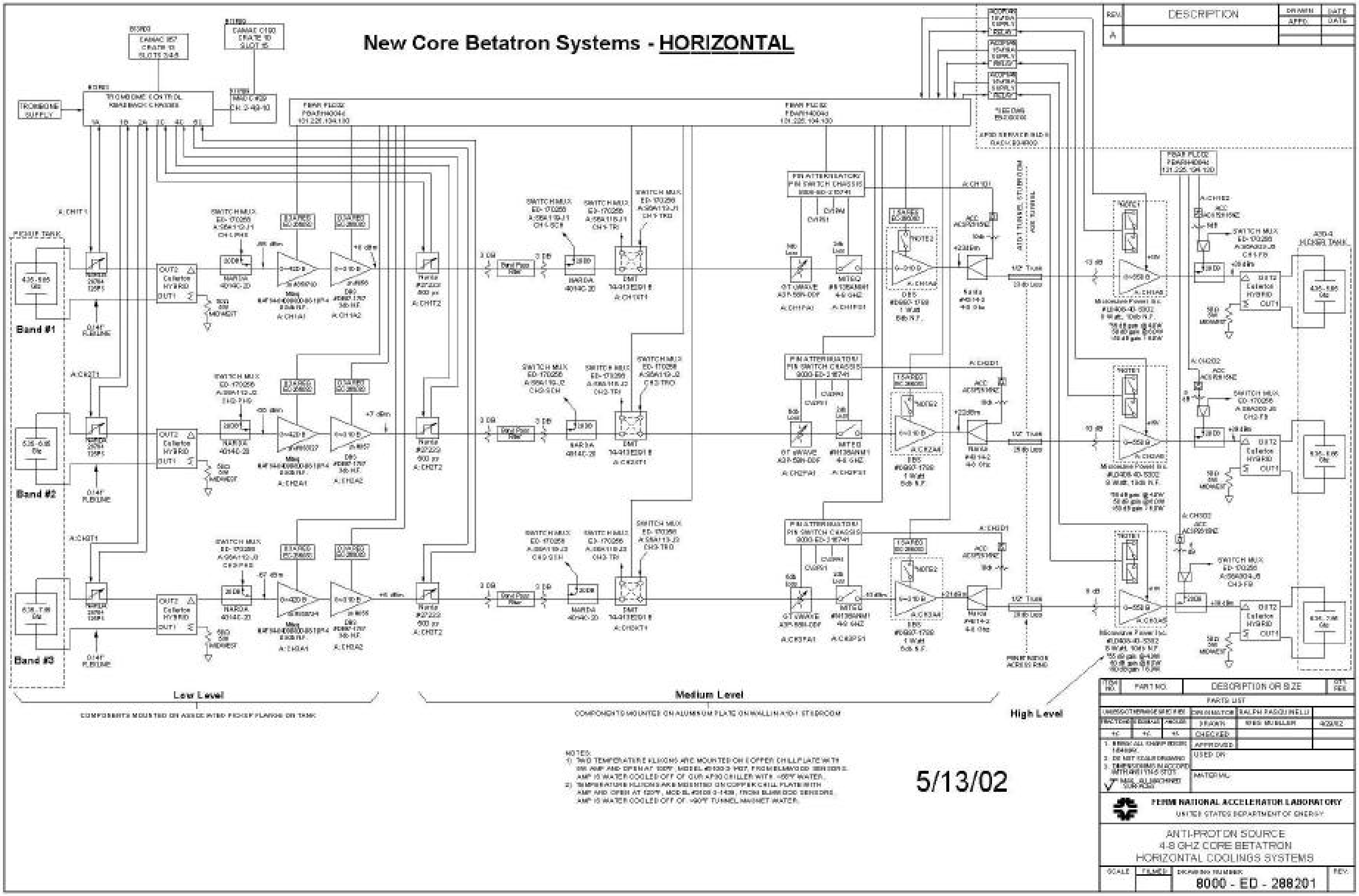
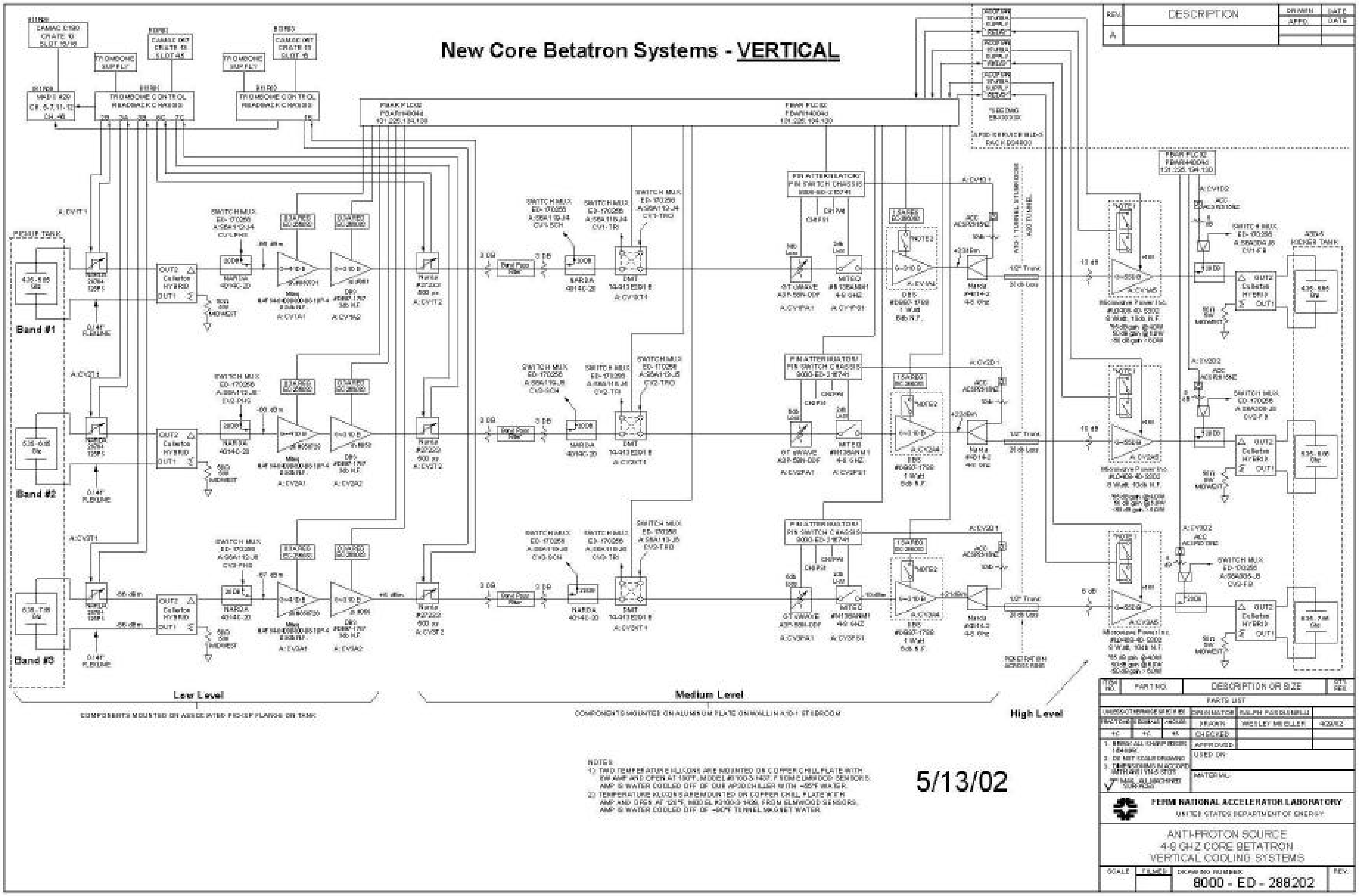







New Core Betatron Systems - HORIZONTAL
Band #1
Band #2
Band #3
Low Level
Medium Level
High Level
5/13/02
DESCRIPTION
DESCRIPTION OR SIZE
PARTS LIST
RALPH PASQUINELLI
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
ANTI-PROTON SOURCE
4-8 GHZ CORE BETATRON
HORIZONTAL COOLINGS SYSTEMS
8000 - ED - 288201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Band #2
Band #3
Low Level
Medium Level
High Level
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DESCRIPTION OR SIZE
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UNITED STATES DEPARTMENT OF ENERGY
ANTI-PROTON SOURCE
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VERTICAL COOLING SYSTEMS
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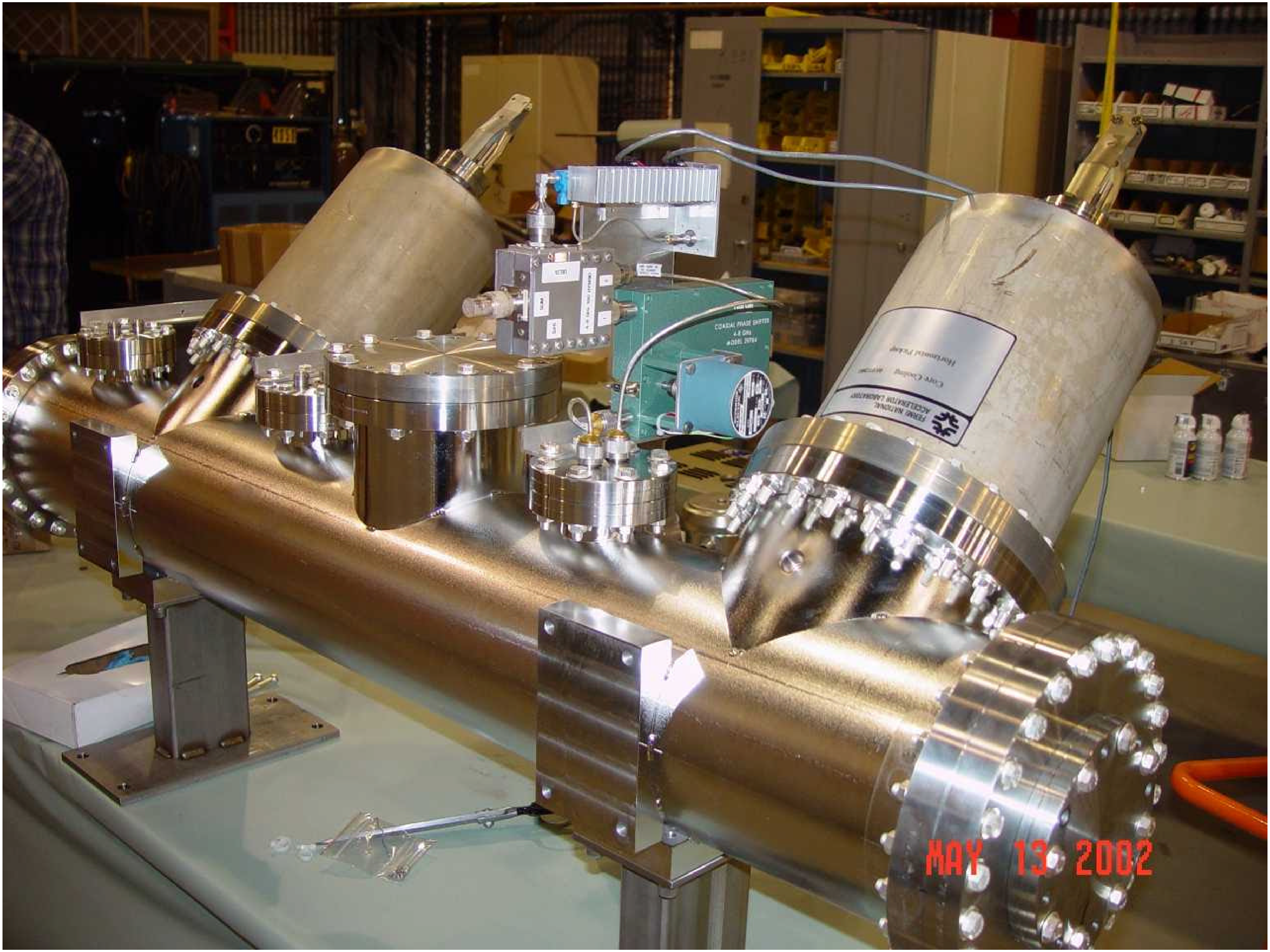
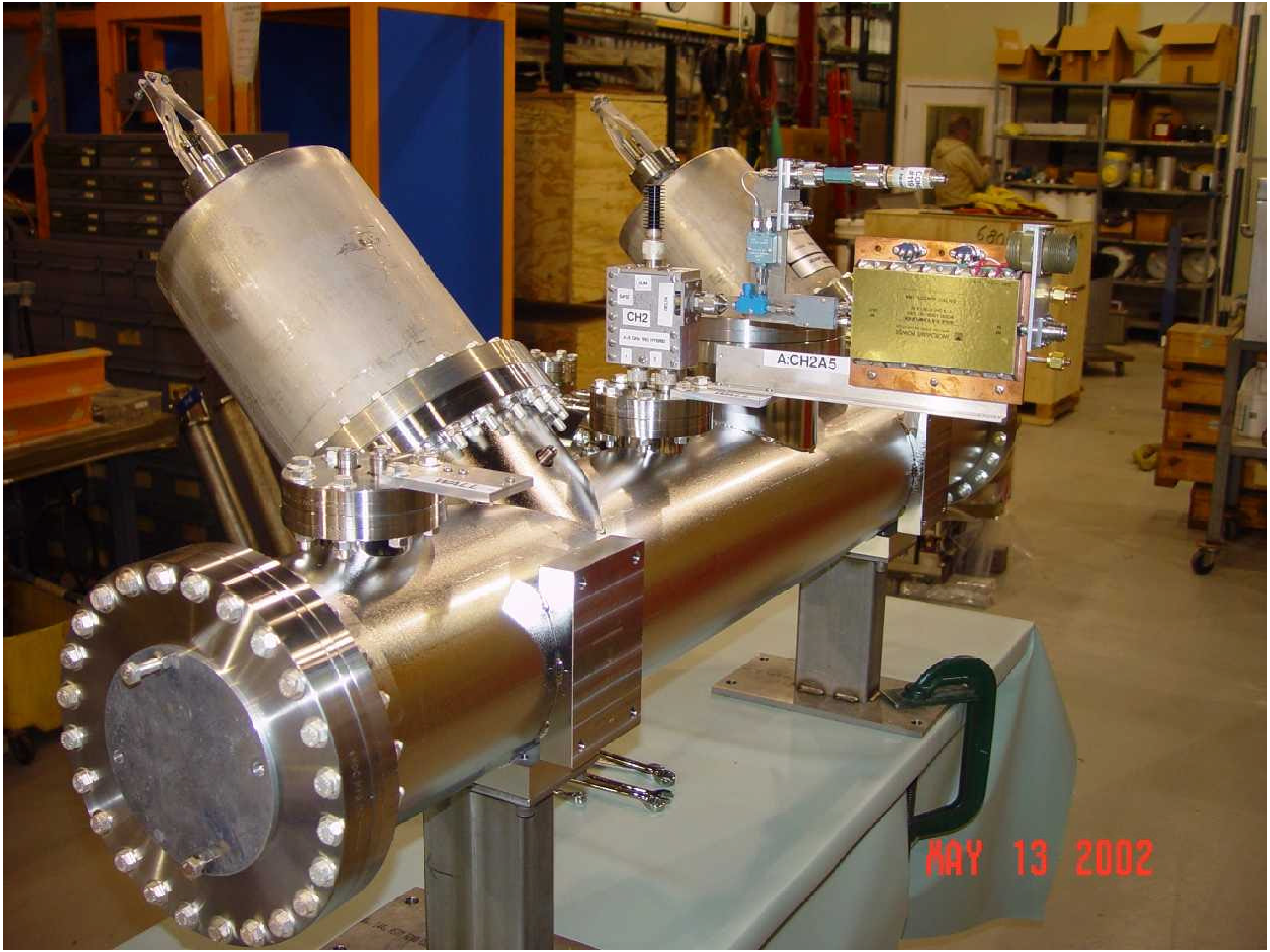
8000 - ED - 288202
5/13/02


MAY 13 2002


UP
Kimberly-Clark
Kaydry EX-L
MAY 13 2002


CH2
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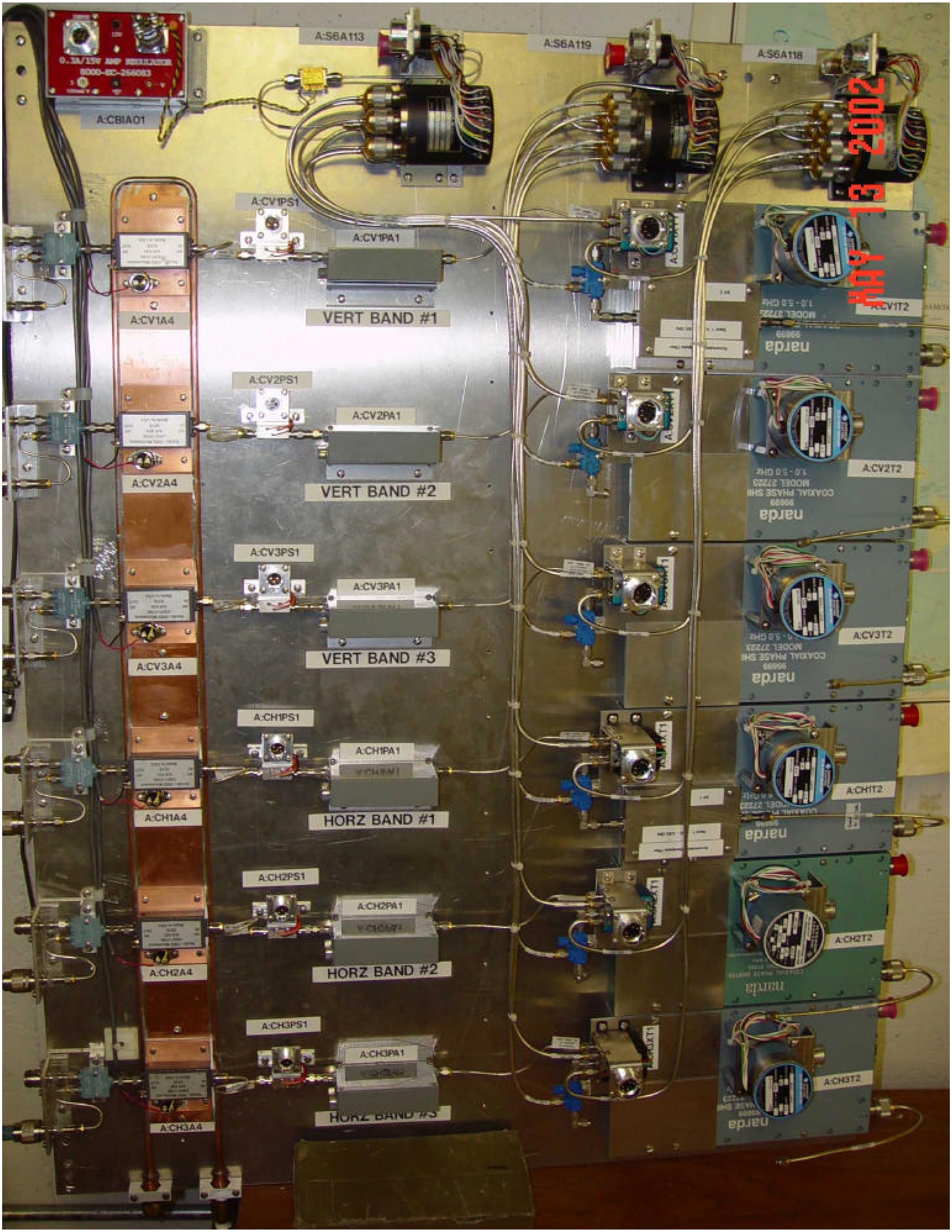
MAY 13 2002


UP
UP
UP
CV2
LYON
MAY 13 2002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MAY 13 2002
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A:CV1PA1
A:CV1A4
VERT BAND #1
A:CV1T2
narda
A:CV2PS1
A:CV2PA1
A:CV2A4
VERT BAND #2
A:CV2T2
narda
A:CV3PS1
A:CV3PA1
A:CV3A4
VERT BAND #3
A:CV3T2
narda
A:CH1PS1
A:CH1PA1
A:CH1A4
HORZ BAND #1
A:CH1T2
narda
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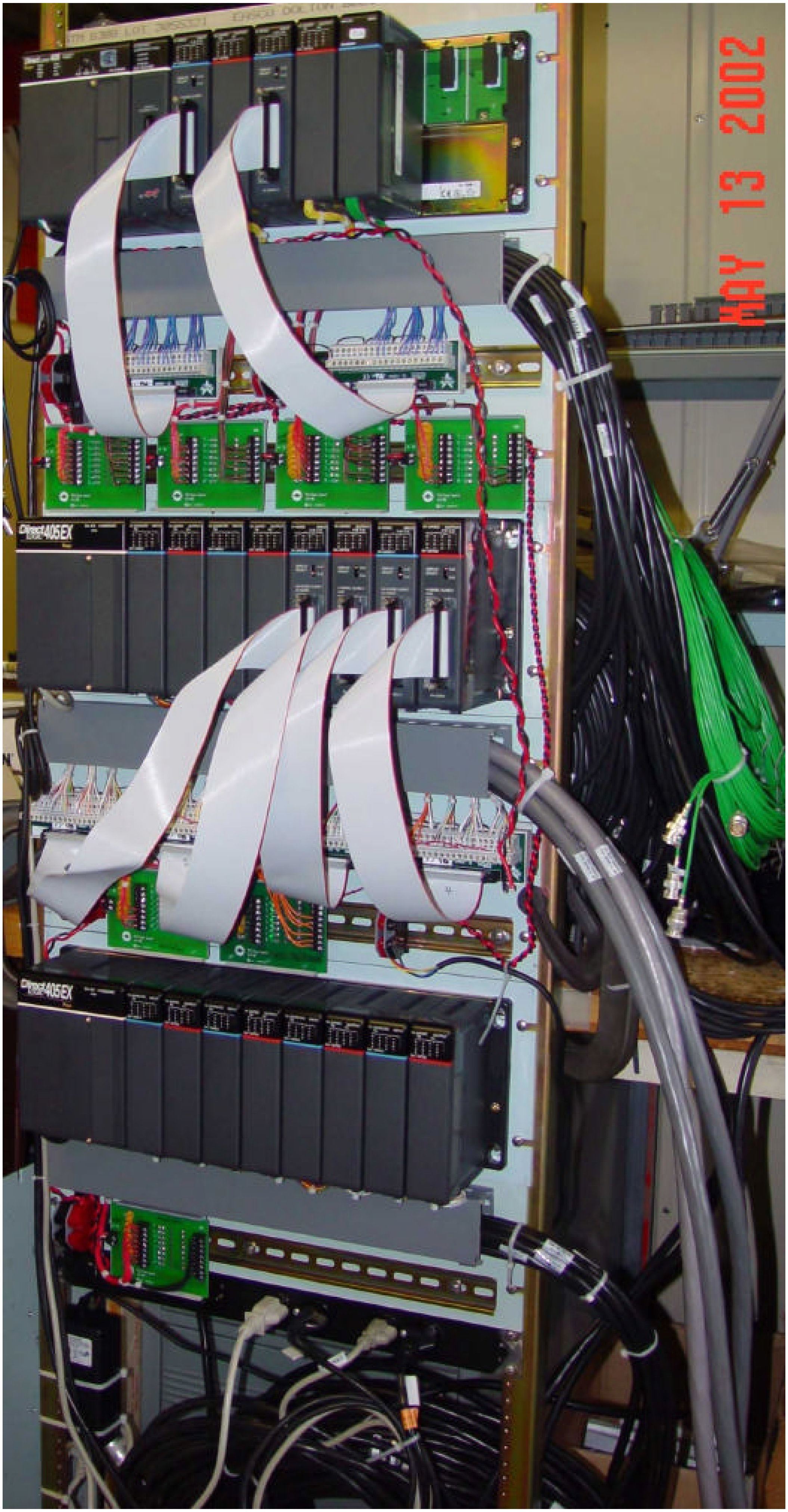

MAY 13 2002

<u>4-8 Ghz. Core Upgrade</u>
<u>Electrical Installation Schedule</u>

Day #1 Shut down all stacktail and core TWT's. Strip all A30 kicker and both A10 core pickup tanks. Remove old core medium and high level electronics. Remove old core PLC. Terminate 8W amp control and readback cables.

Day #2 Complete any needed cable pulls (Trombones). Check (repair if possible) kicker tank A30-1 tank flange B1. Begin installing new core PLC and medium level electronics. Begin terminating trombone cables. Determine length and begin terminating switch tree 1/4" heliax cables.

Days #3-5 Complete installation of new core PLC. Complete terminating and testing of trombone and 1/4" heliax cables. Install pickup to medium level 1/2" heliax cables. Get database entries completed.

Days #8-10 Complete core graphics pages. Recover needed parts from the old core. Complete assembling pickup electronics. Measure all heliax cables. Install all pickup switch tree cabling. Test and repair as needed as much of PLC, trombones, and switch tree as can be done at this time. Complete the removal of all the old core equipment (laser links).

Days #11&12 Install new core pickup and kicker tank electronics including water, switch tree cables, and trunk cables. Reconnect all A30 stacktail kicker tanks. Completely test and measure everything via the control system.

STOCHASTIC COOLING TANKS

<u>During the first six days of the shutdown, I think we will only need six people working twelve hours a day. Anymore people and we will be tripping over each other.</u>

This is my schedule for installation of the four tanks at A-10 & A-30

Day #1 surveyors and RF Technicians work on stripping tanks of controls.
Remove shielding blocks at north hatch APO, and lower in rigging equipment and tanks and etc.

Day #2 Remove tanks at A-30 and A-10 and strip off all necessary parts and install on replacement tanks.

Day #3 Install A-30 tanks and survey, and hookup vacuum and baking control.

Day #4 Install A-10 tanks and survey, then hookup vacuum and baking control.
Pull out old tanks and replace shielding boxes

Day #5 leak checking of A-30 and A-10 while Jim Budlong runs baking control test of A-30 and A-10 sections.

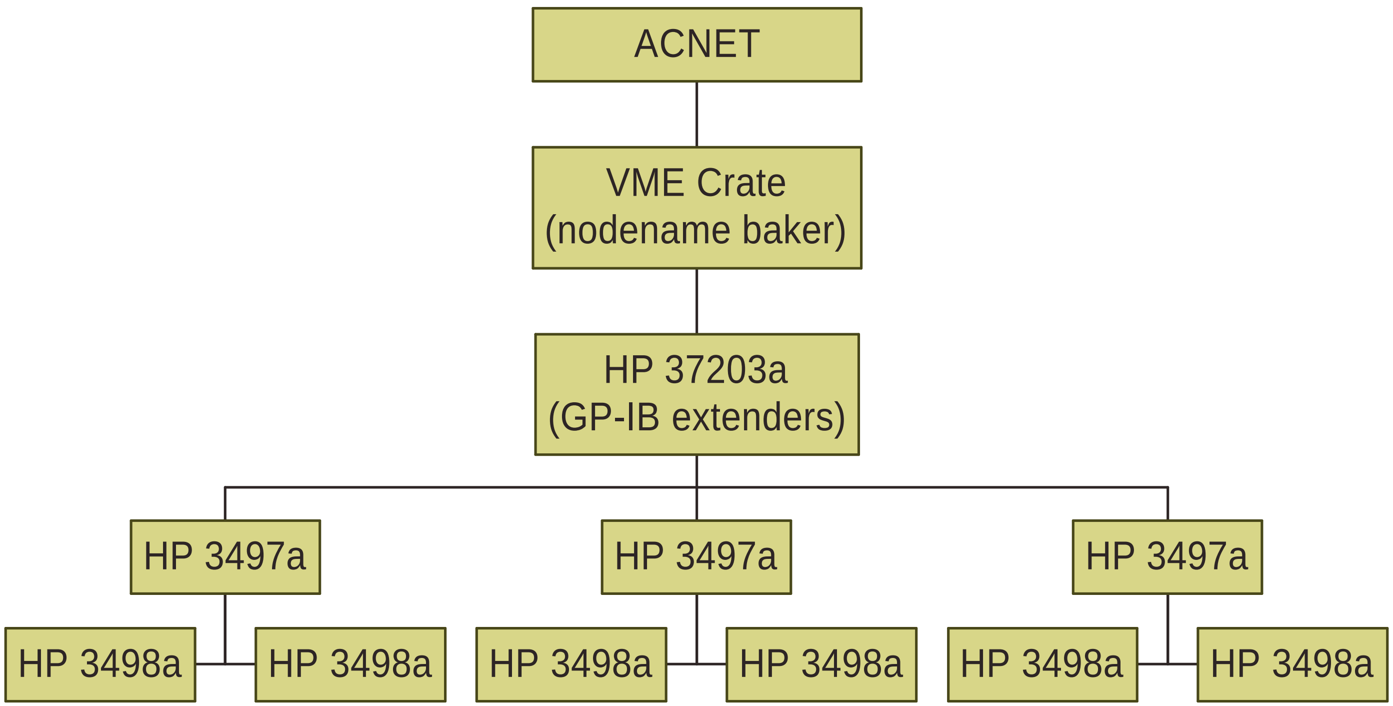
Day # 6 Wrap sections for baking and start running the bake for five days with one day used for unwrapping, cooling down, fire TSP, degassing, and ETC.

<u>From the six day on we won't need anymore than three people to monitor the bake.</u>

Day # 10 unwrap sections so they can cool off, TSP degas.

Day # 11 RF technicians hookup equipment.
Vacuum tech Fire TSP, run RGA scans, and repair leak if found. Tools and equipment removed from the tunnel.

Accumulator Vacuum Bake Out System



System Description

- *ACNET*
- *VME node (baker) running closed loop monitoring (type T Thermocouples) and control (temperature ramps) program; talks "GP-IB" to the downstairs control system*
- *GP-IB extenders (HP 37203a) link upstairs to downstairs*
- *HP 3497a/3498a multi-channel I/O systems in tunnel*
- *20 thermocouples (type "T") per "doghouse" input cards multiplexed into a 14 bit DVM*
- *16 channel/card relay output cards – control relays for heater control*
- *5 cards (either type) per 3497a, 8 cards (either type) per 3498a*
- *700+ thermocouples, 600+ control channels distributed around the ring.*

Accumulator Core 4-8 GHz Transverse Cooling Commissioning

- System timing will not be ruled by system layout. Trunk signals will be transmitted over half inch coax from stub room 10-1 to 30. The original cooling systems were installed this way with ample left over delay. This new system has solid state amplifiers that are four nanoseconds shorter that the TWTs they are replacing.

- Stacking pbars in the accumulator without transverse core cooling has recently been demonstrated at stacking rates exceeding 5 mA per hour starting from zero current.

- All electrical hardware and controls have been checked before installation. All control system links will be tested in the tunnel before commissioning.

Task	Time Hours
Stack 5-10 mA pbars	2
Measure all six system transfer functions	1
Make access to adjust cable lengths	4
Stack 5-10 mA pbars	2
Verify timing on all six transfer functions	1
Total time	10

The above estimate is conservative based on the amount of time to do the actual work. It could easily take twice as long or longer if access to the accelerator and machine restart are problematic.